TABLE 8. Large Civilian R&D Project Share of Agency Budgets (In percent)

	1990	1991	1992	1993	1994	1995	1996
Three Largest DOE Civilian Projects	10	9	17	22	25	25	28
Three Largest NASA Projects	16	16	17	19	22	24	25

SOURCE: Congressional Budget Office.

NOTE: DOE = Department of Energy
NASA = National Aeronautics and Space Administration

TABLE 9. Inflation-Adjusted Spending on Large Civilian R&D Projects (Budget Authority, in billions of 1990 dollars)

	1990	1991	1992	1993	1994	1995	1996
Inventory	4.0	4.4	5.3	5.8	6.3	6.7	6.8
Three Largest Projects	2.1	2.3	2.7	3.3	3.9	4.5	4.8

SOURCE: Congressional Budget Office.

A similar situation could develop if the Congress chooses to fund General Science, Space and Technology (function 250) at levels below the Administration's plan and, at the same time, funds the largest projects at their planned levels. For example, funding the largest projects as planned with function 250 restricted to the CBO baseline--the 1991 level increased for projected inflation only--reduces funds available for other science and technology activities to $5 billion below the Administration's plan by 1996 (see Figure 9). Were spending for function 250 even more restricted to a freeze at its 1991 level, and the largest projects funded as planned, the funds remaining for other activities within function 250 would be almost $9 billion less than the Administration has proposed for 1996. In the past such restrictions on spending might have been less likely. The Budget Enforcement Act, however, maintains discretionary spending at levels between a freeze and the CBO baseline through 1995, implying that at least some types of domestic spending will be frozen or actually decline over the period.

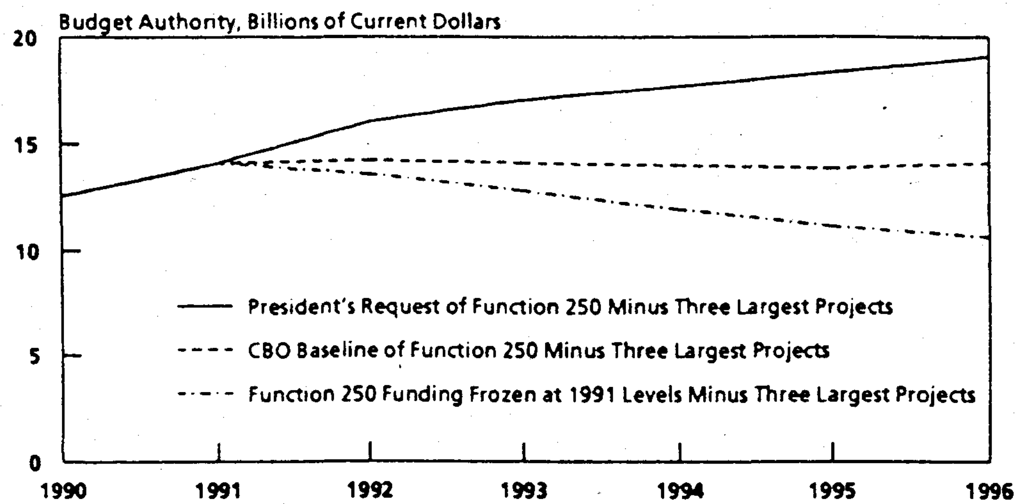
LARGE CIVILIAN R&D PROJECTS AND OTHER SPENDING

A comparison of large R&D project spending in the early 1980s with that projected for the middle 1990s shows differences in the relationship between funding for large projects and for other purposes. In the early 1980s, the data support the impression that the shuttle and other large R&D projects were funded at the expense of the remainder of R&D spending. Neither the budget functions supporting science and technology spending, nor the science and technology agencies' budgets, were on the increase in the first three years of the 1980s (see Table 10). Budget authority for domestic discretionary spending as a whole was essentially flat during the period. Thus, large R&D project spending, measured by the inventory and largest projects methods, took up for a larger share of the budget functions supporting science and technology at the same time that these functions were being allotted a smaller share of a roughly constant level of domestic discretionary spending.

The relationship between the space shuttle and other NASA projects is the most dramatic instance of a large R&D project crowding out other R&D spending in the 1980s. As the American Association for the Advancement of Science (AAAS) noted in its review of the R&D budget for 1983, "funding requirements for the space shuttle have been large and growing, but the rest of NASA's budget has been subjected to an increasingly tighter squeeze."[17] As the AAAS describes the situation, the Office of Management and Budget, when dealing with the unanticipated increases in the cost of the shuttle system in a tighter than expected fiscal environment, considered NASA's program as consisting of two parts--the shuttle and other spending. R&D for the shuttle grew in inflation-adjusted terms and other R&D did not, a decision in which the Congress concurred. There is no evidence that the shuttle funding problem spilled out of the NASA budget into other agencies, such

17. American Association for the Advancement of Science, *Research & Development AAAS report VII: Federal Budget-FY 1983 Impact and Challenge* (1982), pp. 31-35.

Figure 9.
Alternative Projections of Spending for General Science, Space, and Technology Minus the President's Request for the Three Largest Projects, 1990-1996



SOURCE: Congressional Budget Office.

NOTE: Function 250 covers spending on general science, space, and technology.

TABLE 10. Federal R&D-related Spending
(Budget authority, in billions of dollars)

	Functions 250 & 270[a]	Civilian Research and Development[b]	Department of Energy (Civilian projects only)[c]	National Aeronautics and Space Administration[a]	National Science Foundation[a]
1981	18.4	18.0	7.6	5.6	1.1
1982	20.0	14.7	7.7	6.2	1.0
1983	18.8	14.4	6.2	7.1	1.1
1984	16.7	15.7	4.4	7.5	1.3
1985	17.9	17.1	5.3	7.6	1.5
1986	15.3	17.2	3.3	7.8	1.5
1987	16.0	18.9	2.6	10.9	1.6
1988	16.4	20.2	3.4	9.1	1.7
1989	17.0	22.8	3.6	11.0	1.9
1990	19.6	25.9	4.3	12.3	2.0
1991	21.7	29.6	4.5	14.0	2.3

SOURCE: Congressional Budget Office calculated from *Budget of the United States, Fiscal Year 1992*, Part Seven, pp. 54-59; and three publications of the National Science Foundation, Division of Science Resources Studies: *Federal R&D Funding by Budget Function*, various years; "Federal Funds for Research and Development, Detailed Historical Tables, Fiscal Years 1955-1990," no date, and "Selected Data on Federal Funds for Research and Development, Fiscal Years 1989, 1990, and 1991," December 1990.

a. Total budget authority.

b. Includes operations and construction.

c. Total budget authority less nuclear weapons budget authority.

as NSF. Indeed, the slower growth in other NASA efforts and other science and technology spending during the period is in part attributable to the overall economic and budgetary situation of the time. But the priority given the shuttle in part represents a choice of large R&D efforts over other science and technology spending within NASA's budget--a choice that some observers fear will be made again when the space station is being developed in the first half of the 1990s.

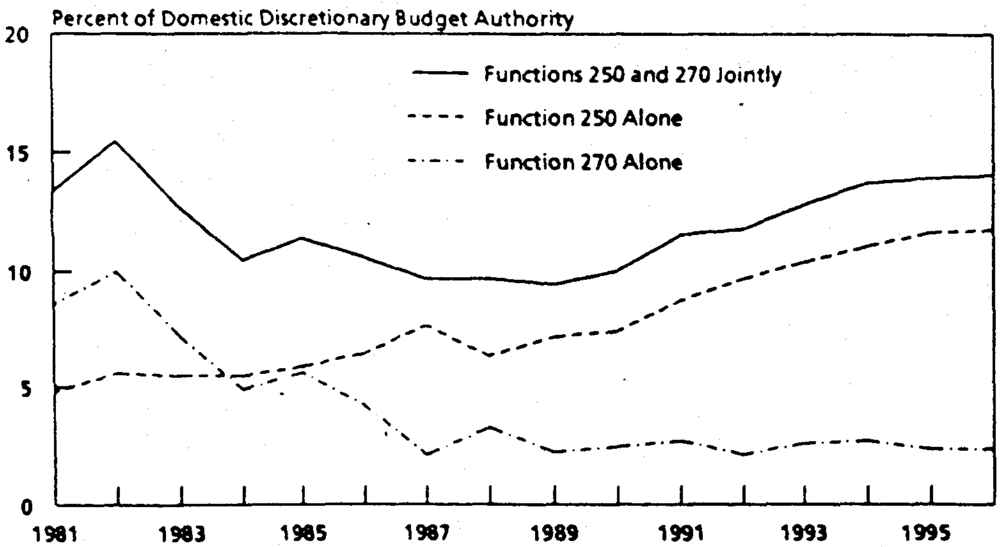
Projections of the same data for the mid-1990s present a different picture. The Administration's plan would increase the level of spending for budget functions and agencies supporting science and technology, while all domestic discretionary spending would be held roughly constant (see Figure 10). Increases in function 250 and 270 would be necessary for the very largest projects, but other R&D spending would also grow. A review of agency-level and R&D budgets supports this view. NASA's overall budget is planned to rise in the 1992 through 1996 period by 15 percent in real terms--not as rapidly as the largest projects but rapidly enough to allow small increases in other spending. NSF's budget for its inventory of large R&D projects is projected to grow only slightly more rapidly than NSF's total budget during the forecast period, although it may vary from year to year, but both would enjoy substantial increases.

The plan for DOE is different. Under the Administration's plan, DOE's funding for other missions decreases, while funding for large projects increases. Funding for DOE civilian programs other than the large R&D programs decreases by 30 percent after adjusting for inflation. Since part of the DOE nuclear facilities cleanup also must be paid out of these funds, DOE programs other than large R&D project and nuclear cleanup may find themselves under severe funding pressures.

These interpretations of the budgetary history of spending for large R&D projects, and of the Administration's program for the 1990s, should be treated with caution. Specifically, one cannot say with certainty that had big projects been funded at lower levels in the past, or not at all, smaller projects would have fared any better than they did. The counterclaim is often made that big R&D projects actually draw funds to agencies undertaking the projects, rather than crowding out other R&D spending. Actual budgetary results are in most cases the outcome of negotiations, so a fuller analysis of this process would be necessary before one could say definitively that the big R&D projects of the early 1980s actually crowded out other R&D spending.

As for the 1990s, the Congress may not accept the intent of the Administration. If the Executive's preference for increasing the priority afforded all R&D is not accepted, or if the cost of science and technology projects increases, then the issue of choosing between large projects and other R&D spending will be a matter for negotiation among the Office of Management and Budget, the Executive Branch line agencies, and the Congress and its committees.

Figure 10.
Spending in Budget Functions 250 and 270, 1981-1996



SOURCE: Congressional Budget Office.

NOTES: Function 250 covers spending on general science, space, and technology. Function 270 covers spending on energy.

Data for years 1992-1996 reflect the President's request.

CHAPTER IV
BUDGETARY OPTIONS

The prominence of large R&D projects in the budget raises questions as to whether their results justify their costs. Quantitative measures of the productivity of science and technology spending are crude. They provide little guidance as to how much to spend and how to distribute funds among projects. A useful principle in making difficult choices of this type is to diversify expenditures, because the level and timing of benefits produced by any particular project or area are uncertain.

In the effort to maintain a balance between spending for large R&D projects and other science spending, the Congress has several options. It could make a periodic review of federal spending on R&D, fund large projects on a multiyear rather than annual basis, set annual spending caps for large projects, cancel one or more of the largest projects, and establish new (and more equal) partnerships with other countries in funding the largest projects.

LARGE R&D PROJECTS AND PRODUCTIVITY

The federal agencies and scientists proposing large R&D projects hold that large R&D projects are productive. Advocates of the Superconducting Super Collider (SSC), or the space station maintain that the benefits of their projects exceed their costs, and are at least equal to those of other projects and programs, including that of reducing the federal deficit. No objective standard exists by which to gauge the of these claims.

The Case for Large R&D Projects

The case for large R&D projects as productive investments is twofold. First, in many areas of science and technology only larger, more expensive facilities can provide answers to fundamental questions. Moreover, only the government can bear the cost and risk of these enterprises and bring their benefits to society. For example, in making the case for the SSC, the Department of Energy and the community of experimental particle physicists argue that progress in experimental physics requires ever larger and more costly particle accelerators. Similarly, advocates of the human exploration of space hold that the space station program is the "next logical step" in a progression leading to human exploration of the solar system.

A second argument for large R&D projects is that large-scale facilities provide the foundation for productive small science. The progression of instruments and facilities in NASA's astronomy program illustrates the point: Supporters view the three large orbiting astronomical facilities included in the inventory of large R&D projects--the Hubble Space Telescope, the Gamma Ray Observatory, and the Advanced X-ray Astronomical Facility--as infrastructure that will support many users in the future. Unlike earlier efforts, which were carried out with short-lived satellites designed and directed by small teams of investigators, these new spacecraft will provide observation time to many investigators over a longer period of time. Longer operating life is not without cost, however. For example, NASA has requested $250 million in 1992 for the Hubble Space Telescope, to cover the cost of repair, refurbishment, maintenance, operation, and data analysis. Likewise, the Earth Observation System and the Advanced Photon Source, which are also envisioned as infrastructure open to many scientists, will require operating funds over a number of years.

These arguments provide qualitative justifications for investment in large science projects. They do not, however, enable one to evaluate the trade-off between large and small efforts within an area, or the best distribution of large and small efforts among scientific disciplines and technical fields. There is no standard by which to evaluate the benefits of federally supported science and technology. Much of the federal support is of projects that involve the production of public goods. Since public goods are not produced by private businesses, and are not traded in private markets, it is difficult to place a value on them. Even the "spillover" benefits to private business of advances in science and technology have proved difficult to measure.[18] Attempts have been made to measure the productivity of scientific programs indirectly on the basis of the number of publications produced by those who participate in them, but these have been inconclusive.[19] Sometimes the relative cost of a project becomes the de facto measure of its worth, and large projects are seen as being less valuable simply because they are more expensive.

The Case Against Large R&D Projects

The general arguments against large R&D projects are more numerous and varied than those for them, but ultimately no more subject to validation. In many respects, they resemble the criticisms brought against the development and production of major weapons systems. Like weapons, large R&D instruments and facilities are costly to develop, build, and operate. Estimates of their cost and capability are subject to great uncertainty. The failure of a large R&D project can be devastating to the research communities depending on it. For example, if NASA proves to be unsuccessful in correcting its communications problem with the Galileo mission to Jupiter, a single malfunction will have aborted a large effort by the planetary research community. Large R&D projects can also have long gestation periods, from conception to political acceptance, development, and eventual operation. During this

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18. Congressional Budget Office, *How Federal Spending for Infrastructure and Other Public Investments Affects the Economy*, Chapter IV (June 1991).

19. For a review of issues related to the value of science and technology spending, including bibliometric measures of output, see, Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade* (May 1991), Chapter 2 and pp. 244 and 245.

time, advances in technology can render all or part of a large R&D project's hardware or mission obsolete.[20] The long gestation period of large R&D projects, particularly in space sciences, also handicaps Ph.D. candidates if their experimental field is overly dependent on the development of large instruments or facilities.

At the center of concern about large R&D projects is their potential to crowd out other R&D projects during the political process of making decisions about the distribution of funding for science and technology.[21] Executive agencies may prefer large projects to small projects, because the former provide budgetary support over a longer period. Large R&D projects offer an executive agency an opportunity to broaden its Congressional support, but along with this support goes a political commitment to keep funding large projects even if cost overruns or shortfalls in agency funding force cutbacks in other R&D spending. Large projects may be favored because of the economic benefits they bring to local communities. Once they are initiated, the momentum of large R&D projects gathers strength from the beneficiaries of project spending in both the public and private sectors.

These beneficiaries--both private corporations and not-for-profit scientific centers and institutes-enjoy an advantage relative to their small-science competitors because they have more resources at their disposal with which to influence the political process in support of their efforts. Recently, some concern has been expressed that spending for large science projects has more to do with bolstering agency budgets, supporting large private contractors, and generating local economic benefits than contributing to scientific and technical progress. Smaller R&D efforts, however, are not immune to this type of criticism. For example, the Office of Management and Budget held that in 1990 some $130 million in funding for small R&D projects was "earmarked" by the Congress for projects that might not have been funded on productivity grounds alone.[22]

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20. For example, recent discoveries using tabletop instruments have shed important light on the "technicolor" theory. Testing the theory has been among the scientific justifications for the SSC. See SSC Central Design Group, *Conceptual Design of the Superconducting Super Collider* (Berkeley, Cal.: SSC CDG, 1986), p. 29. For information on recent experiments, see Malcolm Browne, "Simple Device Produces Record-Breaking Cold," *New York Times*, May 28, 1991, p. C1.

21. See, for example, William J. Broad, "Big Science: Is it Worth the Price?" *New York Times*, May 27, May 29, June 5, June 10, June 19, September 4, October 9, and December 25, 1990; Robert Park, "Mega Science, Mega Bucks," *Washington Post*, October 21, 1990, p. C1; and Phil Kuntz, "Pie in the Sky Big Science is Ready to Blast off," *Congressional Quarterly*, April 28, 1990, pp. 1254-1260.

22. *Budget of the United States Government, Fiscal Year 1990*, p. 90.

The Congress could pursue several options if it wanted to assure a balance between large R&D projects and other R&D spending in the first half of the 1990s. These include undertaking additional legislative oversight of the entire science and technology budget, providing multiyear appropriations for large R&D projects, placing annual spending caps on large R&D projects, canceling or deferring the largest R&D projects, and entering into more-equal partnerships with other countries to fund, operate, and benefit from large R&D projects.

Adopt a Regular Cross-Cutting Policy Review

The Office of Technology Assessment has proposed that the Congress undertake a biennial review of overall science and technology spending.[23] Among the issues considered would be the interplay between large R&D projects and other science and technology spending. Hearings would be held to weigh priorities for federal spending on science. The hearings might assess the degree to which these programs correspond with broad national goals--for example, in education and human resources development--and with specific objectives such as increasing our understanding of global climate change or of superconducting materials. The review would cut across agency budgets in order to produce estimates of total federal support for various areas of science and technology, as well as less precise indicators of the contribution of federal R&D spending to more general purposes.

A cross-cutting review would clarify the extent to which the current distribution of R&D funding is consistent or inconsistent with national goals and objectives. If inconsistencies were revealed, corrective action could be undertaken to achieve a better distribution. The rationale for the review is that the question whether R&D funds are properly distributed hinges as much on an ignorance of the full implications of the current distribution as on a willingness to improve that distribution.

A cross-cutting review would duplicate aspects of the legislative process, particularly the annual budget process. Authorizing committees periodically review the overall national effort.[24] The budget committees consider both the goals and the trade-offs among different science activities in their annual review of function 250. For example, the committees have reviewed the three largest R&D projects proposed for the 1990s, and funding for the National Science Foundation, in each of the last several years. Funding for two of the three largest planned efforts for the 1990s, and NSF, is contained in the same appropriations bill. The existing legislative processes may fall short of the systematic, step-by-step review of goals and objectives

23. Office of Technology Assessment, *Federally Funded Research: Decisions for a Decade*, p. 21.

24. See, for example, *American Science and Science Policy Issues*, Chairman's Report to the Committee on Science and Technology, House of Representatives, 99:2, December 1986.

envisioned for a cross-cutting review. The current process, however, offers the advantage of legal authority to take corrective actions.

A full review of all federal science and technology spending would nevertheless offer some advantages. It would enlighten the current process by providing a forum that transcended budget functions and agency jurisdictions, allowing the Congress to question overall resource allocation--including that between large and small projects. Moreover, as the Office of Technology Assessment notes, a cross-cutting review would allow the Congress to ask the Executive how it sets its spending priorities and justifies them in terms of broad national objectives. Requiring a biennial statement of both the priorities and the process of setting them from the President's Office of Science and Technology Policy and Office of Management and Budget would be consistent with this aspect of a cross-cutting review.

Multiyear Appropriations and Annual Spending Caps

Multiyear appropriations can be an effective means of controlling the total cost of a large project, if the technology of the project is well understood. With its funding assured, the sponsoring executive agency can minimize the total cost of a project by proceeding on an optimal schedule, rather than one dictated by the availability of funds on an annual basis. Predictability is a key ingredient in determining the success of multiyear appropriations. For example, in the defense area, assured funding has been found to be more successful in reducing total costs in the production of already developed weapons systems than in the development phase of new weapons where cost uncertainties are greater.[25] These findings suggest that multiyear appropriations may not necessarily be effective in controlling the total cost of large civilian R&D projects, which are more like weapons development then weapons production. But advocates of multiyear appropriations counter that Congressional actions requiring year-to-year changes in the funding profile for large R&D projects are themselves a cause of cost overruns and would be less of a problem were multiyear appropriations adopted.

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25. Several CBO studies of the Department of Defense's development and procurement of weapons systems shed light on the relation between program costs and multiyear appropriations. "Alternative Strategies for Increasing Multiyear Procurement," Staff Working Paper (July 1986), reports cost savings in production programs where multiyear funding commitments were used.

    The point is reinforced in a second report, *Effects of Weapons Procurement Stretch-Outs on Costs and Schedules* (November 1987), that demonstrates the converse: program costs can be increased by stretch-outs and changes in available funding. Another report, *Concurrent Weapons Development and Production* (August 1988), demonstrates the effect that uncertainty can have on program costs in advancing the tentative conclusion that programs that moved forward into production, but still carried the uncertainties of the development phase, experienced substantial cost overruns.

From a legislative perspective, multiyear appropriations would mean losing the oversight and budgetary control provided by annual appropriations. This drawback becomes more important at a time when the Budget Enforcement Act has already limited spending options. For example, if the largest R&D projects were granted multiyear appropriations at a time when overall agency funding levels have been restricted, other R&D spending could suffer disproportionately.

Arbitrary annual spending caps on large projects are another option. They would help strike a balance between funding for large R&D projects and other R&D spending, given uncertainty as to the cost of projects and their ultimate benefits. While multiyear appropriations might aim at achieving the lowest total cost of developing a large R&D project, annual spending caps would explicitly sacrifice this advantage for predictable annual levels and to protect other R&D spending from being crowded out. Annual spending caps, in addition to raising total program costs, would impose an additional opportunity cost by delaying the delivery of the scientific benefits expected from a large R&D project.

Spending caps and similar arbitrary rules are already being used to control the effect of large R&D projects on other R&D spending. The 1991 Appropriations Conference Report limited the annual rate of growth for the space station program to 10 *percent*, and capped its total appropriation at $2.6 billion annually.[26] Within NASA's program, an informal rule holds that the largely unmanned space science and applications programs should receive funding equal to 20 percent of the agency's spending on research and development and space flight in order to assure that these programs are not underfunded as NASA pursues manned space flight programs. One can even see the Administration's stated policy of doubling NSF's 1987 budget by 1994 as an arbitrary device to assure balance.

Cancel Large R&D Projects

Canceling one or more of the largest R&D projects would be the ultimate form of budgetary control the Congress might choose to exercise in assuring that large projects do not crowd out smaller ones. If the Congress chose to fully fund the Administration's request, and the largest projects did not experience cost overruns, residual funding for other science and technology activities would increase during the next five years (see Figure 9). However, if fewer funds were made available and the largest projects fully funded as proposed, funding of others would be forced down. For example, were the Congress to fund function 250 for 1992 through 1996 at the level of a freeze, while fully funding the largest projects, spending on other science and technology would be more than $3.5 billion below the 1991 level by 1996. Canceling the space station in this circumstance, and retaining the funds within function 250, would soften the decline in funds available for other activities, leaving residual spending over $2.5 billion above what it would be if the station was funded,

26. House of Representatives, Report 101-900, to Accompany H.R. 5158, 101:2 (1990), p.41.

but still $800 below the 1991 level. The situation would be less difficult if funding was provided for function 250 at the higher level of the CBO baseline. The boost provided to residual funds available for other science and technology activities would be less if either EOS or SSC was canceled since each of these projects is less costly than the space station.

The major direct cost of this option would be the loss of future benefits.[27] Moreover, in the case of two of the largest projects, the space station in particular, there would be an additional cost: a loss of international prestige, since the United States would have to break its current international commitments.

Increase International Cooperation

All three of the largest projects in the current U.S. inventory are planned to include international cooperation. In each project, however, the United States is in the role of senior partner and carries the bulk of the cost in exchange for retaining control and the benefits of national procurement necessary for building large instruments.

More equal international partnerships with Canada, Europe, Japan, and possibly the Soviet Union could potentially lower the cost to U.S. taxpayers of large R&D projects. The major costs of more equal international partnerships would be loss of the intangible benefits of U.S. predominance in a particular area and of operational control and procurement.[28] Partnerships of this type would work best were the Congress to provide multiyear appropriations, and hence a loss of legislative flexibility could also be among the costs of this option.

A disadvantage to the United States of increased cost sharing with other countries would be to reduce procurement benefits. For example, in high-energy physics, a new accelerator might be built in Europe rather than Texas. More important, procurement of the technical components (together with whatever potential for spinoffs those procurement contracts might entail) would be spread over a larger number of national contractors. This, in theory, might reduce the benefits coming from science to the U.S. industrial base.

27. CBO has reviewed the costs and benefits of the three largest projects in several different publications. For the space station and EOS, see Congressional Budget Office, *The NASA Program in the 1990s and Beyond* (May 1988) and *Reducing the Deficit: Spending and Revenue Options* (February 1990), pp. 219-223. For the SSC, see *Risks and Benefits of Building the Superconducting Super Collider* (October 1988).

28. For a discussion of the advantages and disadvantages of international cost sharing, see Congressional Budget Office, *Risks and Benefits of Building the Superconducting Super Collider* (October 1988), pp. 51-53 and 63-70.

To say that "big science" procurement contracts give U.S. firms monopoly benefits, however, is to overstate the case. Other industrialized nations also undertake large science projects, and the technical personnel often move around geographically. Furthermore, the specialized nature of many of the technical components of these large science instruments limits the ability of contractors to translate expertise in one contract into more general expertise. For example, the ability of a final contractor to build 15-meter superconducting magnets will not necessarily be of assistance in other areas because the superconducting magnets used in medicine and industry are typically much shorter than 15 meters.

APPENDIX
MEASURES OF "BIG SCIENCE" SPENDING AGGREGATES

This appendix details some of the methods and data that were used in developing measures of spending for the paper.

MEASURES OF "BIG SCIENCE"

The measures of spending for large R&D projects discussed here are:

- The inventory of large projects measure;
- The fields of research measure; and
- The R&D plant measure.

The fourth measure used in the paper, spending on the three projects receiving the most funding in a given year, is a special use of the inventory and so is not discussed separately in the appendix.

The Inventory of Large Projects

The relevant agencies provided all the data for the inventory directly to CBO, or indirectly through their budget submissions (see Table A-1).

National Aeronautics and Space Administration Projects. The inventory developed by William C. Boesman is used as a starting point for the CBO inventory of NASA projects. Boesman's inventory excluded expenditures for developing the space shuttle and other investments in space transportation, but these are included in the CBO inventory. The Boesman inventory included all projects with a total cost of $25 million (in 1984 dollars) or more. The CBO inventory includes only major satellite and facilities class projects, as NASA refers to them.

Department of Energy Projects. DOE provided its data in budget authority, with one exception--the Clean Coal Technology Program, which provided its data in obligations. In the latter program, the Congress has already provided advance budget authority for five rounds of cooperative agreements. Because the authority is being obligated only as DOE enters cooperative agreements with its various partners, taking over 10 years in some cases, obligations were used as the best measure of program funding. Data for 11 large Clean Coal Technology projects that DOE had agreed to as of March 1991 were included.

TABLE A-1. MEASURES OF SPENDING FOR LARGE CIVILIAN R&D PROJECTS, BY AGENCY
(Budget authority, in millions of dollars)

Year	National Aeronautics and Space Administration		Department of Energy		National Science Foundation
	Inventory	Three Largest Projects	Inventory	Three Largest Projects	Inventory
1980	2,793	2,547	692	341	92
1981	3,166	2,932	701	337	106
1982	2,627	2,415	832	381	102
1983	4,138	3,902	792	379	119
1984	675	434	748	305	159
1985	1,005	623	655	252	195
1986	1,045	530	558	225	204
1987	1,224	736	631	247	226
1988	1,173	673	745	257	234
1989	1,823	1,185	806	304	288
1990	2,704	2,008	1,034	433	304
1991	3,141	2,307	1,188	420	292
1992	3,634	2,694	1,763	759	337
1993	4,135	3,322	2,027	1,071	399
1994	4,871	3,993	2,020	1,214	447
1995	5,541	4,764	2,029	1,239	473
1996	5,758	5,146	2,161	1,366	489

SOURCE: Congressional Budget Office.

National Science Foundation. The NSF provided data on annual outlays. CBO converted these data, which combine the construction and operation, into budget authority. The conversion formula was based on the historical relationship between NSF total R&D outlays and budget authority. Since the formula was based on the relationship between total R&D outlays and budget authority, it was applied to the sum of the facility series rather than to the experience of any single facility. The formula explained over 96 percent of the relationship between the two data series on which it was based.

The Fields of Research Measure of Science Spending

The fields and subfunctions included in this measure are:

DOE Energy Programs	Fission, Fossil, Fusion, Supporting Research, and Uranium Enrichment
DOE General Science Programs	Nuclear and High-Energy Physics, and the Superconducting Super Collider
NASA Programs	Space Transportation, Space and Terrestrial Applications, and Space Science

This measure does not include any activities of the National Science Foundation and the National Institutes of Health, because of the multidisciplinary nature of the subfunctions in the former and the small size of the instruments in the latter.

CBO constructed this measure from three data sources: NSF data on the conduct of R&D by function and field within agencies; NSF historical data on federal obligations for R&D plant by agency; and DOE budget submissions.[29] NSF data provide R&D spending broken down by budget function, subfunction, and agency for 1980-1991. The NSF R&D plant series was used for NSF and NASA facilities and large equipment, while DOE budget submissions allowed creation of a consistent series of DOE civilian facilities' spending.

29. National Science Foundation, *Federal R&D Funding by Budget Function* (various years). See also Division of Science Resource Studies, National Science Foundation, "Federal Funds for Research and Development; Detailed Historical Tables: Fiscal Years 1955-1990," no date, and "Selected Data on Federal Funds for Research and Development, Fiscal Years 1989, 1990, and 1991," December 1990. It should be noted that different National Science Foundation data series use slightly different definitions because they are collected from different surveys for different purposes. Consequently, there may be slight discrepancies between data series. For instance, federal R&D spending for 1990 totals $63.8 billion, $66.1 billion, $68.5 billion, or $69.2 billion depending on the NSF data series.

For example, DOE R&D is divided into energy spending (function 270) and general science (function 250).[30] Within energy R&D, spending is further divided into various program areas: fusion, fossil, fission, conservation, renewable, uranium enrichment (including only part of this category, much of which is considered production), environmental R&D, and supporting research technical analysis. NSF and NASA have a similar division by budget function and field.

The NSF published series on R&D by budget function purports to include only operating expenses. Consequently, it excludes construction projects, if they are defined as such. However, if the project is defined as a cooperative agreement, as was the Clinch River Breeder Reactor and as is most of clean coal technology, then spending on it is defined as operating expenses and is included in the series. The result is that the series is neither pure nor consistent (from an economic analyst's point of view) in that some capital projects are in and others are out, based on their legal, rather than economic, treatment.

For this reason, this measure of big science spending includes a constructed capital spending series for DOE civilian R&D for 1980-1991, based on budget submissions for the relevant years. The series includes construction and capital equipment budget authority at the subfunction level. For example it includes magnetic fusion construction and capital equipment, but the spending on any specific fusion project is not broken out. The series also excludes capital projects done under some cooperative arrangement, such as Clinch River. Thus, the series complements R&D data from NSF in that the projects fully paid for by DOE are in this series but not in the NSF series while those done under some cooperative arrangement are in the NSF series but not in the DOE series. Because the two data series complement each other, putting them together results in a consistent and complete series of DOE civilian spending on R&D.

The other major inconsistency in the data lies in NASA's redefinition of several hundred million dollars of annual spending from R&D to operations for 1978-1982. (Since the detailed analysis begins at 1981, some of this problem is mitigated.) Originally NASA labeled much of its shuttle spending as R&D, but after the shuttle became operational NASA retroactively redefined these same expenditures as operations. Thus, for these years the historical R&D data are high. Because CBO included the shuttle as an R&D project in the inventory, for the sake of consistency CBO has also used the historical data that include the shuttle.

30. DOE also has defense R&D activities, which are not relevant to a measure of civilian R&D.

R&D Plant

The NSF publishes historical data on obligations for R&D plant by agency. The definition of R&D plant includes facilities and fixed equipment and their acquisition, construction, alteration, or major repair.[31] This definition excludes predesign studies, office equipment, and movable equipment such as microscopes; NSF claims these should be in a parallel series called the conduct of R&D, discussed above.

SPENDING AGGREGATES

This section presents some of the methods used in creating the aggregates with which the measures of big science were compared. They correspond to the denominators of the ratios discussed in Chapter III. The aggregates are presented in Table A-2.

All Civilian R&D

This series measures all federal nonmilitary R&D spending. It contains both spending on the "conduct of R&D" and spending for plant and equipment, which are left out of many analyses of R&D spending. The data are the same as those used to create the fields-of-science and R&D plant measures discussed above. The data are in terms of budget authority, with the exception of the R&D plant series, which is in obligations.

At the functional level, the aggregate data match the historical budget function data relatively well. For instance, the constructed series combines DOE capital construction budget submission data with the NSF series on conduct of R&D and on R&D plant to create a general science and space function series. This constructed series generally matches the OMB function 250 General Science and Space series for 1980-1991. The average annual error is 2.6 percent.

At the subfunction level, the difference between the two series is sometimes greater: the OMB function 251 general science data series differs from the constructed series by more than 5 percent. By contrast, the constructed series on health research differs from the OMB historical data for function 552 by 1.6 percent for the 1980-1990 time frame, while the space series diverges by 2.2 percent.

The President's budget does not contain a forecast of civilian R&D through 1996. Consequently, CBO projected its civilian R&D series forward based on the President's forecast for the budget functions that account for the vast majority of civilian R&D, namely 250 (General Science and Space), 270 (Energy) and 552 (Health Research). These functions are forecast to grow by 5.5 percent annually

31. See National Science Foundation, *Federal Funds for Research and Development: Fiscal Years 1987, 1988, 1989* (1989), p. ix.

TABLE A-2. R&D SPENDING AGGREGATES
(Budget Authority, in millions of current dollars)

Year	Office of Management and Budget Function 250	Office of Management and Budget Function 270	Office of Management and Budget Function 552	Congressional Budget Office Function 250	Congressional Budget Office Function 270	Congressional Budget Office Function 552	All Civilian R&D[a]
1980	6,251	40,320	3,642	6,251	40,320	3,642	17,667
1981	6,643	11,754	3,757	6,643	11,754	3,757	18,043
1982	7,219	12,770	3,844	7,219	12,770	3,844	14,711
1983	8,155	10,683	4,252	8,155	10,683	4,252	14,412
1984	8,822	7,865	4,773	8,822	7,865	4,773	15,710
1985	9,152	8,758	5,402	9,152	8,758	5,402	7,054
1986	9,286	6,047	5,552	9,286	6,047	5,552	17,188
1987	12,538	3,430	6,660	12,538	3,430	6,660	18,914
1988	10,864	5,526	7,018	10,864	5,526	7,018	20,232
1989	12,949	4,062	7,706	12,949	4,062	7,706	22,761
1990	14,644	4,926	8,324	14,644	4,926	8,324	25,947
1991	16,479	5,180	9,186	16,479	5,909	9,186	29,650
1992	18,934	4,129	9,670	17,096	5,537	9,588	31,281
1993	20,691	5,119	9,931	17,776	6,238	9,968	33,001
1994	22,202	5,509	10,288	18,479	6,489	10,361	34,816
1995	23,665	4,861	10,288	19,217	6,151	10,774	36,731
1996	25,057	4,956	10,288	19,975	6,535	11,197	38,751

SOURCES: Congressional Budget Office; Office of Management and Budget, *Budget of the United States Government, Fiscal Year 1992*, Part Seven, pp. 54-59; and three publications of the National Science Foundation, Division of Science Resources Studies: *Federal R&D Funding by Budget Function* (various years); "Federal Funds for Research and Development, Detailed Historical Tables, Fiscal Years 1955-1990," no date, and "Selected Data on Federal Funds for Research and Development, Fiscal Years 1989, 1990, and 1991," December 1990.

a. Constructed series, including both operations and facilities.

between 1991 and 1996.[32] By this forecast, civilian R&D would grow from 15.7 percent to 18.1 percent of domestic discretionary spending. This growth is indicative of the President's program of increasing the share of federal resources devoted to R&D.

Domestic Discretionary Budget Authority

In order to compare the historical data on domestic discretionary spending with the aggregates for big science discussed above, CBO estimated domestic discretionary budget authority based on historical data for outlays. This estimation was performed by using the historical relationships between budget authority and outlays for the major components of domestic discretionary spending. This relationship was then used for the series as a whole.

Time series data for the budget authority granted to all domestic discretionary activities are not readily available. CBO and OMB, however, have each issued an outlay series of domestic discretionary spending.[33] OMB also has issued time series data for the budget authority and outlays granted to budget functions and subfunctions, and for outlays for discretionary programs by budget function.[34]

The estimate of domestic discretionary budget authority for 1980 through 1990 used in this study is based on the relationship between outlays and authority in budget functions and subfunctions that are primarily composed of domestic discretionary programs, and on CBO's and OMB's total domestic discretionary outlay series. For each year, a ratio of budget authority to outlays was calculated for the total budget authority and outlays of the domestic discretionary budget functions and subfunctions. Total budget authority for domestic discretionary spending was estimated by multiplying both CBO's and OMB's total outlay data for each year by the corresponding year's ratio of budget authority to outlays of the budget functions and subfunctions identified as domestic discretionary.

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32. Calculated from *Budget of the United States Government, Fiscal Year 1992*, Part Seven, pp. 55 and 56.

33. *Budget of the United States Government, Fiscal Year 1992*, Table 8.1, Part Seven-78, and Congressional Budget Office, *The Economic and Budget Outlook: Fiscal Years 1992-1996* (January 1991), Table D-6, p.150.

34. *Budget of the United States Government, Fiscal Year 1992*, Table 3.2 and Table 5.1, Part Seven, and Table 8.3, Part Seven-84.

Budget functions and subfunctions identified as domestic discretionary were determined by comparing function and subfunction total outlays with discretionary outlays by function as presented in the budget.[35] On an outlay basis, the total for these functions and subfunctions for 1980 through 1990 accounted for between 55 percent and 60 percent of the data for total domestic discretionary outlays as presented by both CBO and OMB. The budget functions and subfunctions identified as dominantly domestic discretionary were:

250 General Science, Space and Technology
300 Natural Resources and Environment
400 Transportation
450 Community and Regional Development
501 Elementary, Secondary and Vocational Education
504 Training and Employment
550 Health Research
750 Administration of Justice

35. *Budget of the United States Government, Fiscal Year 1992,* Table 8.3, Part Seven-84.